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# AMBIENT AIR QUALITY IN THE SARNIA AREA

## ANNUAL REPORT 1986

November 1987

Ministry of the Environment
Ontario

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Southwestern Region

# AMBIENT AIR QUALITY

# IN THE

# SARNIA AREA

## ANNUAL REPORT 1986

Technical Support Section

Southwestern Region

ONTARIO MINISTRY OF THE ENVIRONMENT

NOVEMBER 1987

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SUMMARY

Ambient air quality monitoring in the Sarnia area during 1986 revealed that levels of air pollutants are normally low. Levels of total suspended particulates were remarkably low in 1986 and continue to indicate a trend of reduced levels. Levels of sulphur dioxide were satisfactory and the Air Pollution Index remained below the Advisory Level.

Sarnia continues to experience levels of carbon monoxide and oxides of nitrogen that compare favourably with other communities in Ontario and there were no excursions above the criteria for desirable ambient air quality for these pollutants in 1986. There were no measurements of hydrogen sulphide and mercaptans above the criterion for desirable ambient air quality. The criterion is based on odour.

The criterion for ozone was exceeded in Sarnia and at the rural monitoring site east of Sarnia. The excursions were primarily attributable to the long-range transport of ozone into the Sarnia area. The U. S. Environmental Protection Agency is requiring individual states to implement control strategies that will ensure attainment of the U. S. primary air quality standard for ozone by December 31, 1987. These control strategies should reduce the long-range transport of ozone into Ontario. Ontario is also developing control strategies for ozone. New emission standards for Canadian cars starting with 1988 model years should appreciably reduce ozone precursor chemicals.

Fluoride levels south of Courtright continue to exceed the criteria for desirable ambient air quality. However, the criteria are based on the protection of the most sensitive vegetation and Ministry phytotoxicology studies do not reveal vegetation damage off the property of the source.

SOMMAIRE

Dans la région de Sarnia, les mesures de contrôle de la qualité de l'air ambiant effectuées en 1986 montrent que les concentrations de polluants atmosphériques y sont normalement faibles. En 1986, les concentrations totales de particules en suspension se sont révélées remarquablement faibles et continuent actuellement d'accuser une tendance à la baisse. Les concentrations d'anhydride sulfureux étaient acceptables et l'indice de pollution atmosphérique est demeuré inférieur au seuil d'intervention.

À Sarnia, les concentrations de monoxyde de carbone et d'oxydes d'azote restent comparables à celles d'autres collectivités ontariennes et l'on n'a enregistré en 1986 aucun dépassement des critères de qualité de l'air ambiant pour ces polluants. On n'a enregistré aucune concentration d'hydrogène sulfuré et de mercaptans dépassant le critère de qualité de l'air ambiant, lui-même basé sur l'odeur.

Dans le cas de l'ozone, on a enregistré des dépassements du critère à Sarnia et au point de contrôle rural situé à l'est de Sarnia. Les dépassements sont essentiellement attribuables à un apport atmosphérique d'ozone dans la région de Sarnia par transport à grande distance. L'Agence de protection de l'environnement des États-Unis impose actuellement aux différents États la mise en oeuvre de stratégies de lutte qui permettront d'atteindre la norme primaire de qualité atmosphérique pour l'ozone au plus tard le 31 décembre 1987. Ces stratégies de lutte vont permettre de réduire notablement l'apport d'ozone en Ontario par transport à grande distance. L'Ontario prépare lui aussi des stratégies de lutte concernant l'ozone. À partir des modèles de l'année 1988, les nouvelles normes antipollution s'appliquant aux automobiles canadiennes permettront de réduire notablement la production de précurseurs chimiques de l'ozone.

Au sud de Courtright, la concentration de fluorures reste supérieure aux critères de qualité de l'air ambiant. Toutefois, ces critères visent à protéger les végétaux les plus sensibles, et les études phytotoxicologiques du ministère ne détectent aucun dommage pour la végétation à l'extérieur de la propriété de la source.

## INTRODUCTION

The ambient air monitoring network of the Ministry of the Environment measures the levels of a number of pollutants that may directly or indirectly adversely affect health, vegetation or the enjoyment of property. Data on levels of pollutants are compared with Ontario's criteria for desirable ambient air quality. Thus, excursions above these criteria reflect undesirable conditions. Data are also used to determine trends in air quality and therefore, the effectiveness of pollution abatement, as well as to provide information on the effect of specific sources of pollutants and to formulate strategies to control pollution.

Ontario Hydro, the Lambton Industrial Society and private industry also operate ambient air monitors in the Sarnia area. The Ministry also conducts special air monitoring surveys for short periods of time as well as conducting phytotoxicology surveys to determine the effects of air pollutants on vegetation. The results of the special surveys and monitoring by other groups are not contained in this report.

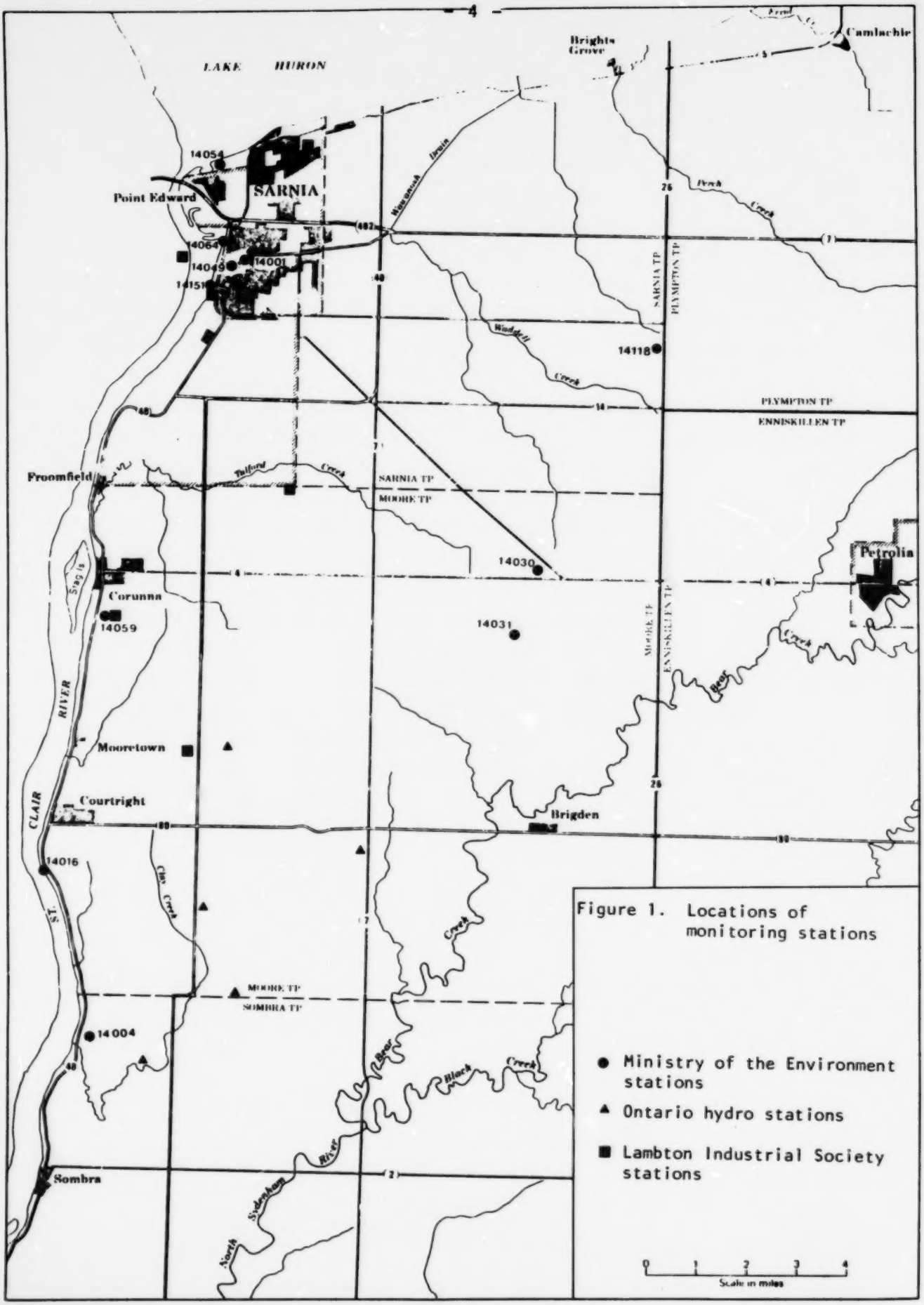
Emissions from industrial and other stationary sources of pollutants in Ontario are regulated by this Ministry through a Certificate of Approval. In the Sarnia area, there is a special control strategy for sulphur dioxide. This special control strategy requires major sources of sulphur dioxide to provide supplementary control if the ambient levels of sulphur dioxide approach the 24-hour criterion for desirable ambient air quality.

## DESCRIPTION OF MONITORING NETWORK

Continuous and intermittent monitors for determining levels of pollutants in ambient air are maintained by the Ministry at sites dispersed through the Sarnia area. However, monitoring is more intensive in the area of downtown Sarnia because it has a higher potential for elevated levels of pollutants than most other areas in Lambton County. This higher potential is a result of the downtown area being affected by emissions from industries and power generating plants to the south, as well as dense vehicular traffic and commercial establishments in the downtown core. The industries and power generating plants to the south of Sarnia tend to be located along the St. Clair River and plumes from different sources of emissions can create an additive impact when they impinge on the downtown area. Furthermore, the taller buildings situated in the downtown core affect wind currents and may bring pollutants from aloft down towards ground level.

The location of the Ministry's fixed monitoring sites are illustrated in Figure 1. Also included in Figure 1 are the locations of monitoring sites of Ontario Hydro and the Lambton Industrial Society. Specific Ministry locations and the pollutants monitored are listed in Table A1, Appendix 1.

Criteria for desirable ambient air quality and the supporting rationale for the establishment of these criteria appear in Table A2, Appendix 1.


LAKE HURON
Brights Grove
Camlachie
SARNIA
Point Edward
14054
14064
14049
14001
14151
14118
Froomfield
Corunna
14059
14030
14031
Petrolia
Mooretown
Courtright
Brigden
14016
14004
Sombra
CLAIR RIVER
SARNIA TP
PLYMPTON TP
ENNISKILLEN TP
MOORE TP
SOMBRA TP
Figure 1. Locations of monitoring stations
Ministry of the Environment stations
Ontario hydro stations
Lambton Industrial Society stations
0 1 2 3 4
Scale in miles

## METEOROLOGICAL DATA

Meteorological data are utilized in predicting the stability of the atmosphere which affects the dispersion of pollutants. These data also assist in identifying sources of elevated levels of pollutants and in validating mathematical models designed to predict the dispersion of air pollutants.

The main meteorological tower in the area is located at station 14016 immediately south of Courtright. Wind speed and direction are measured at 10 metres, 30 metres and 92 metres above ground level. In addition, ambient temperature is measured at the 10-metre level and the gradients in temperature between the 10-metre level and the 30- and 90-metre levels are determined. These meteorological data are transmitted to Toronto by a telemetry system. Meteorologists utilize the data to forecast the stability of the atmosphere. This forecasting feature is an intrinsic part of the Air Pollution Index and the Lambton Industrial Meteorological Alert, both discussed later in this report.

Meteorological data from station 14016 have been used to compute the average concentrations of some pollutants for specific wind directions and to determine the number of hours that the criteria for ozone have been exceeded for different wind directions.

A summary of the frequency of winds for different directions at the 30-metre level of station 14016 appears in Table A3, Appendix 2. The data indicate that the prevailing winds are from the south.

## MONITORING PROGRAM AND RESULTS

### PARTICULATES

Primary sources of man-caused emissions of particulates to the atmosphere are vehicular traffic, materials handling and combustion processes. Wind-blown particulates from open fields, sand and coal piles, roadways and roofs are also significant sources.

Measurements for particulates are reported as total suspended particulates and soiling index. Total suspended particulates are determined by drawing measured volumes of air through a pre-weighed filter for 24-hours and subsequently weighing the quantity of particulates collected on the filter. Soiling index is measured by determining the difference in the amount of light that is transmitted through a filter before and after ambient air is drawn through the filter for 1 hour. The amount of light transmitted through the filter is affected by the quantity, size, shape and opaqueness of particulates retained on the filter. Soiling index can be correlated to levels of suspended particulates and can be determined without the time-consuming laboratory analysis required for determining concentrations of total suspended particulates. For these reasons, soiling index is used as a substitute for suspended particulate values when data are required quickly such as in the Air Pollution Index.

#### Total Suspended Particulates

Two criteria for desirable ambient air quality exist for total suspended particulate matter. One is 120 micrograms of suspended particulates per cubic metre of air ($ug/m^3$) averaged over a 24-hour period. The other is an annual geometric mean of 60 $ug/m^3$. The criterion for 24 hours is based on impairment of visibility and adverse health effects associated with combined concentrations of sulphur dioxide and suspended particulates. The annual criterion is based on public awareness of suspended particulates and property damage.

During 1986 total suspended particulates were sampled at 8 sites in the Sarnia area. At 7 of the sites sampling was conducted on an every-sixth-day schedule for the year while at the remaining site, station 14016, sampling was conducted on a daily basis. The national monitoring networks of the United States and Canada operate on the same every-sixth-day sampling schedule for suspended particulate matter. The Ministry operates the daily schedule at station 14016 to evaluate how representative the every-sixth-day schedule is of the complete year. The 1986 data indicate that the every-sixth-day schedule was reasonably representative of conditions throughout 1986.

Average levels of total suspended particulates in 1986 were similar to the 1985 levels which were the lowest experienced since monitoring began in the Sarnia area. In the Sarnia area the annual criterion has not been exceeded at any monitoring site since 1981. The number of elevated values of total suspended particulate matter was remarkably low in 1986. There were only 2 values above the 24-hour criterion; both detected at the daily monitoring site, 14016, south of Courtright. This has been the first year that the 24-hour criterion has not been exceeded in the downtown area of Sarnia. The lower levels of suspended particulate matter in the downtown area in recent years is most likely attributable to fewer emissions from construction projects associated with the redevelopment of the core area.

A summary of 1986 data for total suspended particulate matter appears in Table 1. Figure 2 shows the annual geometric means and the frequencies of excursions above the 24-hour criterion for 1986 at the approximate locations of the monitoring sites.

Table 1. Summary of 1986 data for total suspended particulates.

| Station No. | No. of samples collected | Annual geometric mean (ug/m_) | No. of values greater than 24-hour criterion | Percentage of Values greater than 24-hour criterion |
|---|---|---|---|---|
| 14001 | 57 | 38 | 0 | 0 |
| 14016 | 343 | 36 | 2 | 1 |
| 14016-S | 59 | 38 | 1 | 2 |
| 14030 | 58 | 33 | 0 | 0 |
| 14031 | 54 | 33 | 0 | 0 |
| 14054 | 58 | 39 | 0 | 0 |
| 14059 | 57 | 34 | 0 | 0 |
| 14064 | 57 | 45 | 0 | 0 |
| 14151 | 59 | 41 | 0 | 0 |

Note: Data from station 14016-S are every-sixth-day sampling results extracted from the daily sampling data for station 14016.

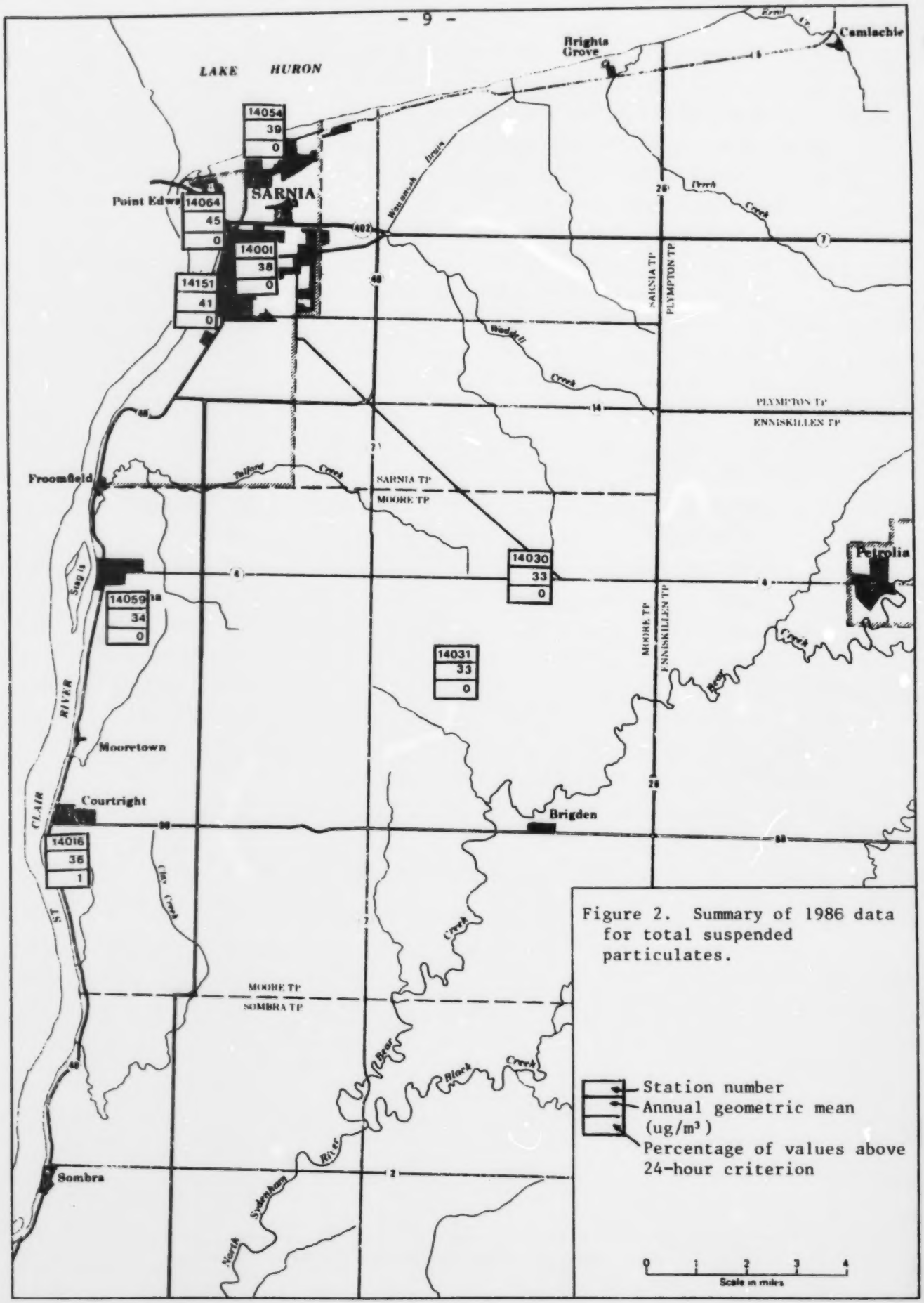



Figure 2. Summary of 1986 data for total suspended particulates.

The trend of improved levels of total suspended particulate matter is illustrated by Figures 3 and 4. Figure 3 shows that for 5 monitoring sites[1] in operation since 1972 the average annual geometric mean has been lowered by more than 50 percent while Figure 4 shows that the frequencies of excursions above the 24-hour criterion have been reduced by over 99 percent.

In general levels of total suspended particulates in the Sarnia area compare very favourably with levels experienced in other areas of Ontario. The results for 1986 are extremely low and can be attributed to both better control of emissions and favourable meteorology.

Chemical Analysis of Suspended Particulates

As part of a Province-wide study, samples of suspended particulates collected at 4 stations in the Sarnia area were analyzed for cadmium, chromium, copper, iron, lead, manganese, nickel and vanadium. For 2 of these stations samples were also analyzed for nitrates and sulphates. A summary of data from 1976 through 1986 for these constituents is contained in Table A4, Appendix 3.

Data for sulphates are erroneously high, based on the findings of several studies of the sampling method utilized by the Ministry. Investigations have not revealed a sampling method that is practical and will provide more accurate results for sulphates while maintaining the accuracy level for the other pollutants.

(1) The stations are 14001, 14016, 14054, 14064 and 14151. Station 14064 replaced station 14049 in 1978 but comparison studies revealed that the levels of suspended particulates were similar at both sites.

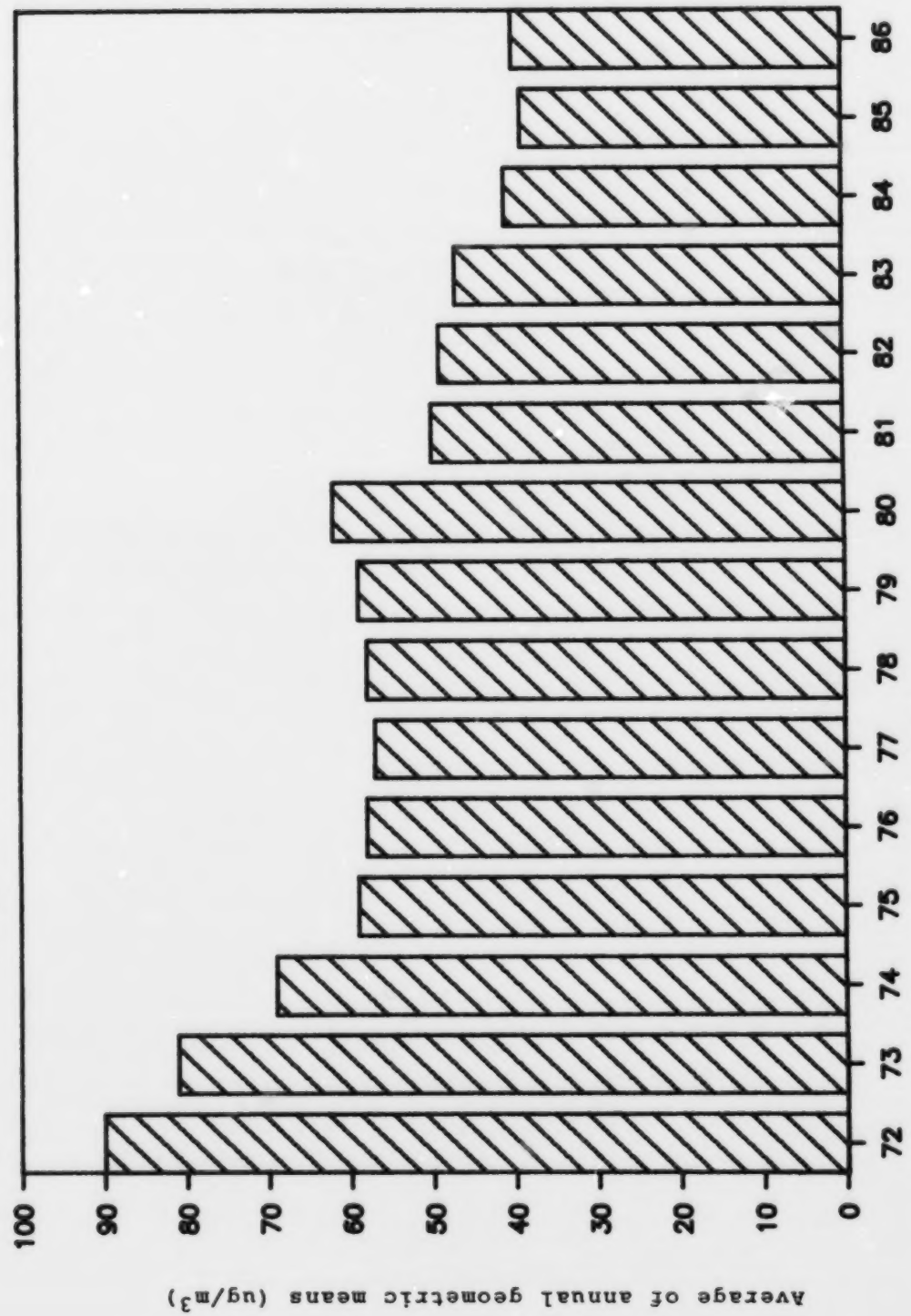
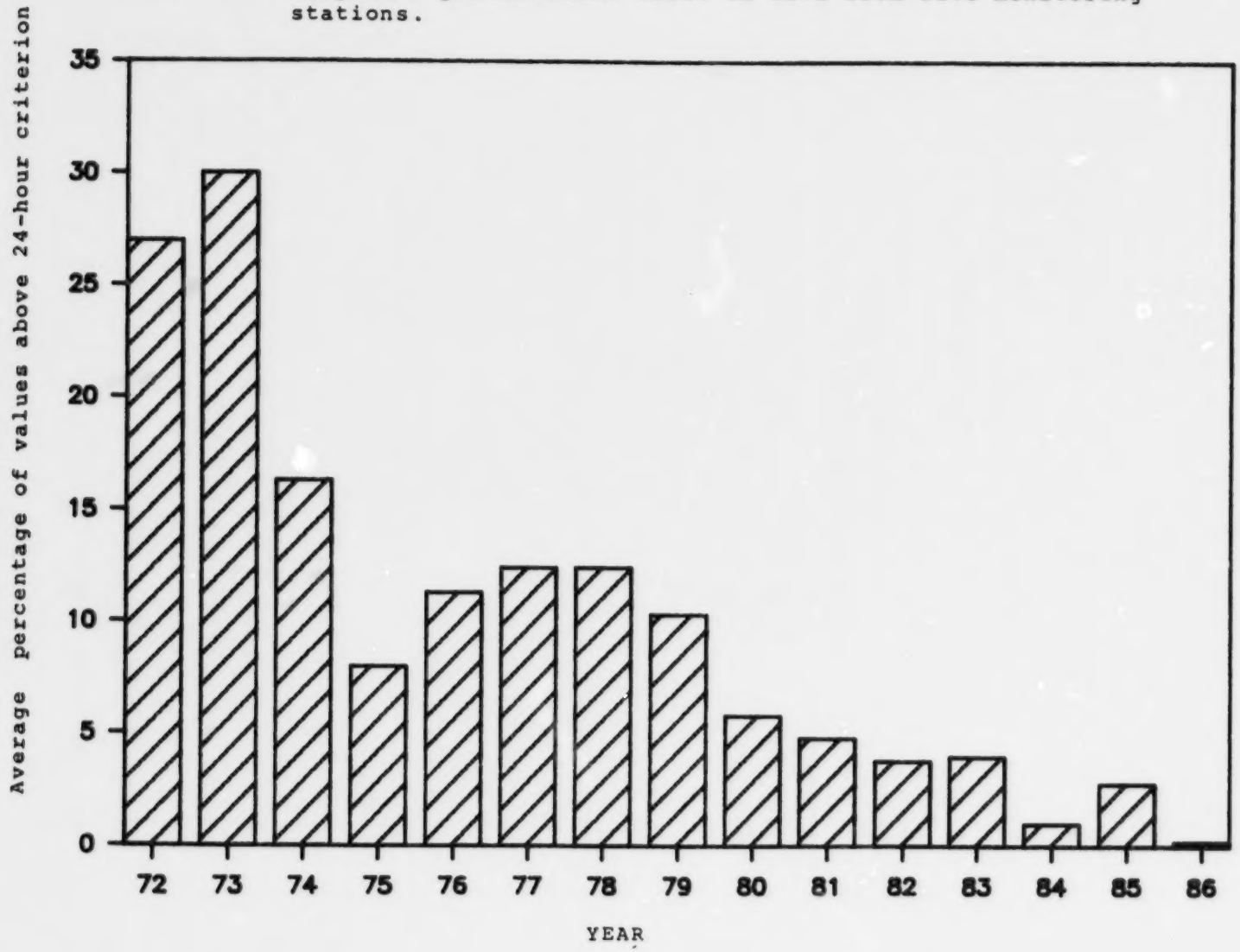



Figure 3. Trend in annual levels of total suspended particulates based on data averaged for five monitoring stations.

Figure 4. Trend in excursions above 24-hour criterion for total suspended particulates based on data from five monitoring stations.



Criteria for desirable ambient air quality exist for cadmium, lead, nickel and vanadium. There have been no values above the criteria and in general, the concentrations of the various metals have been low.

## SULPHUR OXIDES

Combustion of sulphur-containing fuels comprises the predominant source of man-made emissions of sulphur oxides. In the Sarnia area, large quantities of these fuels are consumed by power-generating plants in Michigan and Ontario and by petroleum and petrochemical industries located south of downtown Sarnia.

The Ministry of the Environment monitors sulphur oxides in the Sarnia area using continuous analyzers for gaseous sulphur dioxide and by analyzing suspended particulate matter for sulphate.

Throughout 1986 the Ministry measured gaseous sulphur dioxide at station 14016 south of Courtright and at station 14064 in Centennial Park, downtown Sarnia. There were 11 other sites where monitors providing continuous measurements of sulphur dioxide were operated by Ontario Hydro, the Lambton Industrial Society or private industry. Data for these sites are not included in this report but were utilized to confirm conclusions drawn from the data generated by the Ministry's instruments.

Data are reported as 1-hour average concentrations, 24-hour average concentrations (midnight to midnight) and annual average concentrations. Criteria for desirable ambient air quality are 0.25 parts of sulphur dioxide per million parts of air (ppm) averaged for a 1-hour period, 0.10 ppm averaged for 24 hours and 0.02 ppm as an annual average. The criteria for the 1-hour and annual averages are based on the protection of vegetation while the 24-hour criterion is based on the protection of human health. The 24-hour and annual criterion were not exceeded in 1986. There were 2 hourly values marginally above the 1-hour criterion at station 14064. A summary of the 1986 data appears in Table 2.

Table 2. Summary of 1986 data for sulphur dioxide

| Station No. | Annual average (ppm) | Percentage of values above criterion | | Maximum 1-hour value (ppm) | Maximum 24-hour (daily) value (ppm) |
|---|---|---|---|---|---|
| | | 1-hour | 24-hour | | |
| 14016 | 0.00 | 0.00 | 0 | 0.22 | 0.03 |
| 14064 | 0.01 | 0.02 | 0 | 0.28 | 0.08 |

In the past, there was concern about the frequency of excursions in the downtown area of Sarnia above the 24-hour criterion for desirable ambient air quality. This concern resulted in a new regulation called LIMA[1] being implemented in April, 1981. This regulation requires major industrial emitters of sulphur dioxide to provide additional controls either continuously or when required by the Ministry. The Ministry may require industries to provide increased control when meteorological conditions conducive to adverse air quality are likely to persist and sulphur dioxide levels are elevated at specified monitoring sites. The specific monitoring sites consist of two in Sarnia, one in Port Huron and one in Corunna. One site in Sarnia and the sites in Port Huron and Corunna are part of the Lambton Industrial Society's monitoring network. The other site in Sarnia is the Ministry's station 14064, located in Centennial Park.

(1) Lambton Industrial Meteorological Alert

This control strategy has been very successful. Since the regulation went into effect the 24-hour criterion has not been exceeded at the Ministry's monitoring stations, nor has the Air Pollution Index reached the Advisory Level of 32.

Figure 5 shows the decreasing trend in the frequencies of excursions above the 24-hour criterion at three Ministry monitoring stations. Station 14064 is located in the downtown area, and station 14016 is located south of Courtright. Station 14049 was located in downtown Sarnia but its instrumentation was relocated to station 14064 because of redevelopment in the immediate area of the station. It is very evident that excursions have occurred most frequently in the downtown area and that excursions have not occurred since LIMA was implemented in 1981.

Pollution roses for sulphur dicxide measurements appear in Figure 6. The roses were created using data for wind direction and speed from the 30-metre level of station 14016 and concentrations of sulphur dioxide determined at the various stations. The length of the line corresponding to a specific wind direction indicates the average sulphur dioxide concentration when the winds are from that direction. The rose for station 14064, located in downtown Sarnia reflects appreciably higher levels of sulphur dioxide when winds are blowing from industries located in south Sarnia and further south. However, since the ambient air quality criteria are met the influence of the local emission sources is not creating an apparent problem.

The rose for the station south of Courtright does not reveal any appreciable impact for the emissions of the nearby power generating stations of Ontario Hydro and Detroit Edison.

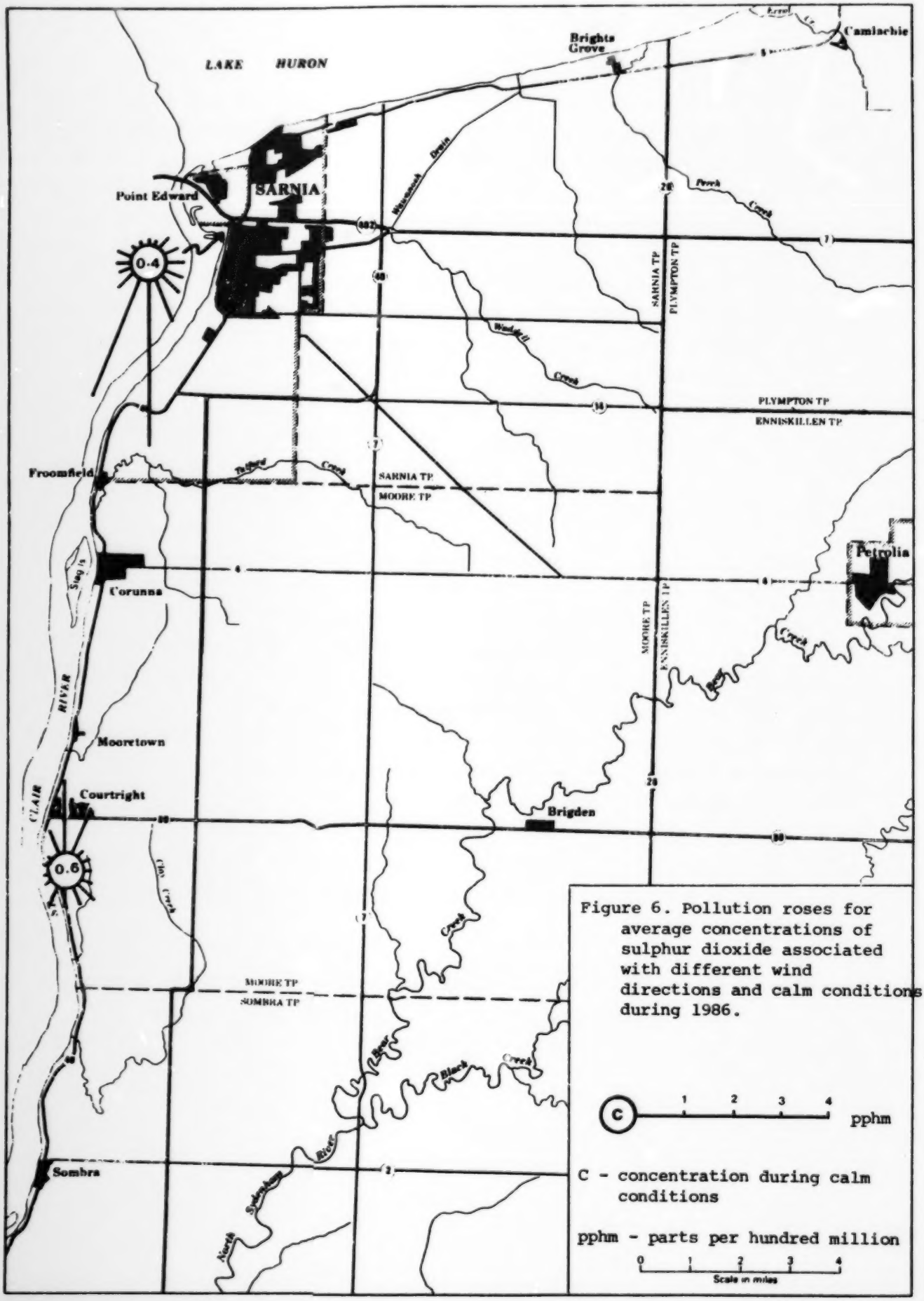
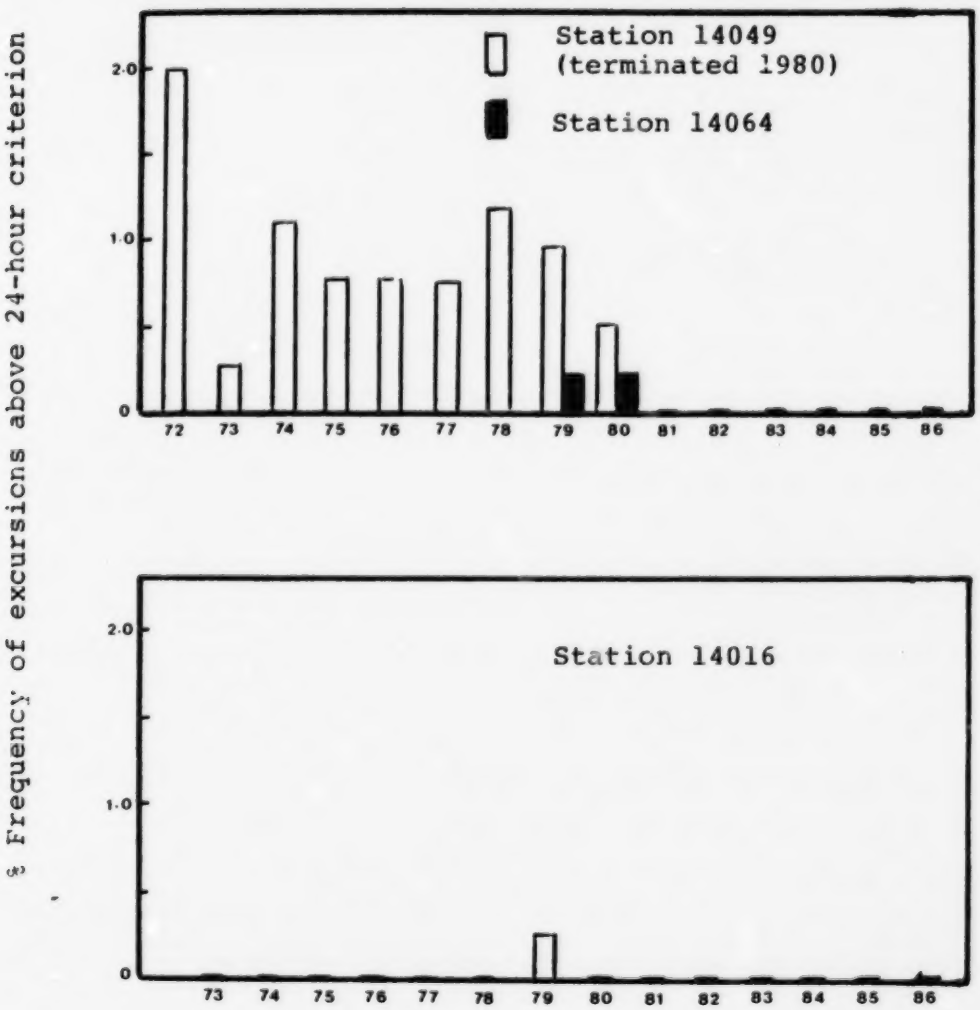



Figure 6. Pollution roses for average concentrations of sulphur dioxide associated with different wind directions and calm conditions during 1986.

C - concentration during calm conditions

pphm - parts per hundred million

Figure 5. Trend in frequency of excursions above 24-hour criterion for sulphur dioxide, 1972 to 1986.



AIR POLLUTION INDEX

The Air Pollution Index (API) is a system designed to control or prevent an air pollution episode. Meteorological forecasting and current readings of sulphur dioxide and suspended particulates are utilized to predict the potential for persistence of pollution conditions that are reported as the API.

Data for suspended particulates are provided by the measurement of soiling index and a correlation between concentrations of suspended particulates and soiling index. Hourly values of soiling index and gaseous sulphur dioxide are used to compute 24-hour running averages which are inserted into the following equation:

$$API = 3.02\ (9.75\ COH + 125.95\ SO_2)^{0.76}$$

where: COH is the 24-hour running average for soiling index expressed in units of coefficient or haze. $SO_2$ is the 24-hour running average for sulphur dioxide expressed in parts per million.

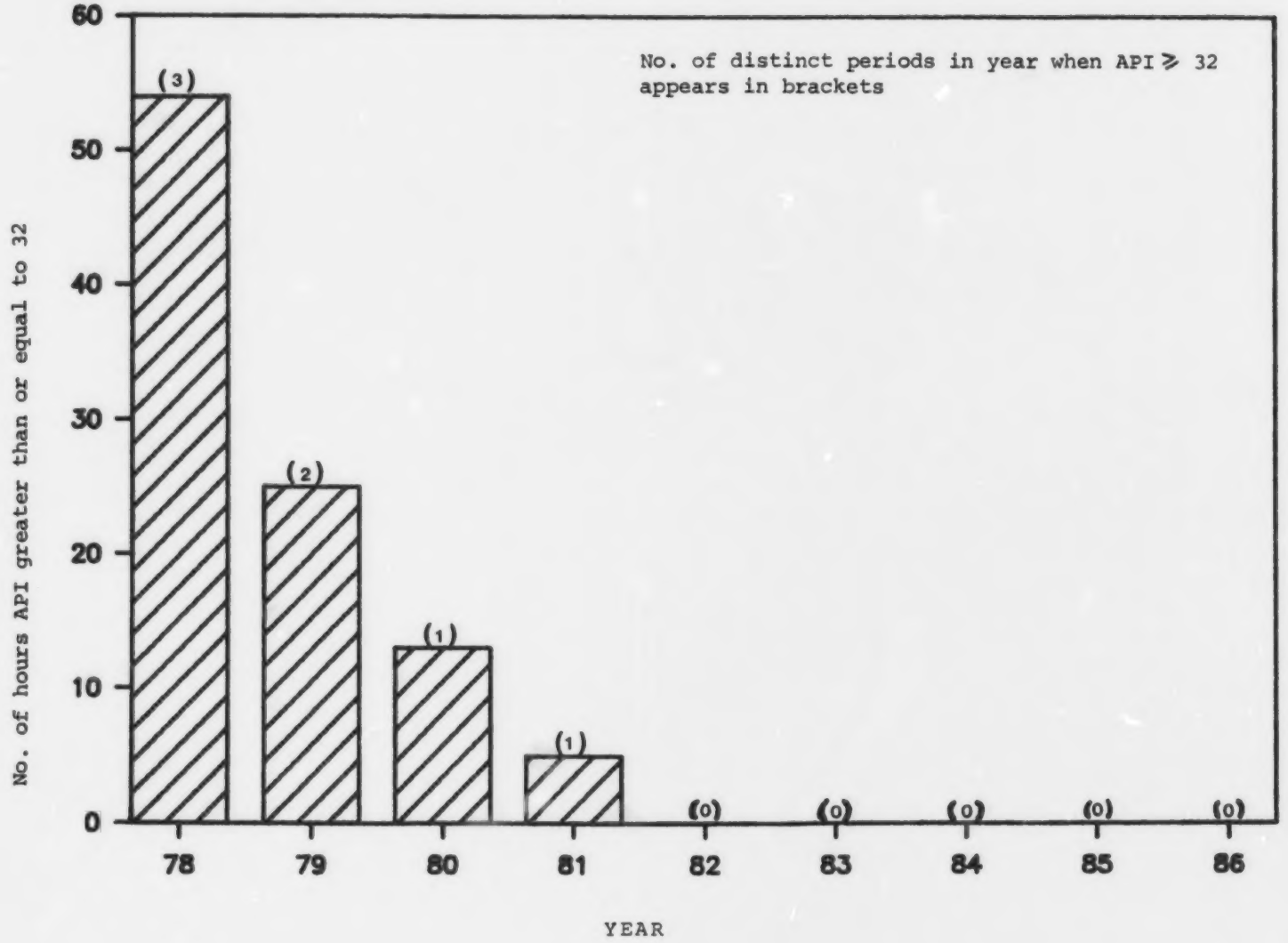
The sulphur dioxide and soiling index data utilized to determine the API for Sarnia are obtained from monitors operated at station 14064 in the downtown core.

API values below 32 are considered acceptable. Values from 32 to 49 are at the Advisory Level and if adverse weather conditions are likely to persist, those responsible for major emissions are advised to prepare to curtail operations. At an API of 50, major emitters may be ordered to curtail operations. At 75, further cutbacks can be required. If the API reaches 100 all contributors of pollution that are not essential to public health and safety may be ordered to cease operations.

The LIMA regulation would result in sulphur dioxide emissions being curtailed well before the API reached 50. A very remote possible exception would be if the soiling index were extremely high and levels of sulphur dioxide were low. Since the API was introduced in Sarnia in December, 1977 it has not reached 50.

Since LIMA was introduced in April, 1981, API levels have been below 32. A favourable comparison between levels in recent years and levels of the initial years of reporting the API can be seen in Figure 7. The annual average for the API was 8.0 in 1986.

Figure 7. Trend in Air Pollution Index Levels



TOTAL REDUCED SULPHUR

Gaseous total reduced sulphur compounds often exhibit malodours at very low concentrations. Mercaptans are reduced sulphur compounds that contain sulphur and hydrogen and exhibit characteristics similar to hydrogen sulphide. Hydrogen sulphide, also a reduced sulphur compound, is commonly referred to as "rotten egg gas" and many mercaptans are also malodorous at extremely low concentrations.

Both hydrogen sulphide and mercaptans originate in nature from anaerobic decomposition of organic matter containing sulphur. In the Sarnia area, the release of hydrogen sulphide and mercaptans into the atmosphere may result from the processing of petroleum feedstocks containing sulphur.

The criterion established to represent desirable ambient air quality with respect to hydrogen sulphide is 0.02 ppm as an average for 1 hour. This criterion is based on the offensive odours exhibited by this gas. Similarly, the criterion for mercaptans is based on odour and was established as 0.01 ppm averaged for 1 hour and expressed as methyl mercaptan.

Unfortunately, the monitoring instrument in Sarnia does not segregate hydrogen sulphide from mercaptans but determines their combined concentrations and reports these concentrations as hydrogen sulphide. For the purpose of this report the combined concentrations of hydrogen sulphide and mercaptans are compared to the less restrictive hydrogen sulphide criterion.

During 1986 monitoring was conducted at station 14064 in the downtown area. There were no excursions detected above the 1-hour criterion. A pollution rose, Figure 8, constructed for total reduced sulphur measurements at station 14064 indicates that higher levels occur when winds are blowing towards the monitoring stations from the industrialized area in south Sarnia. A summary of total reduced sulphur data appears in Table A5, Appendix 4.

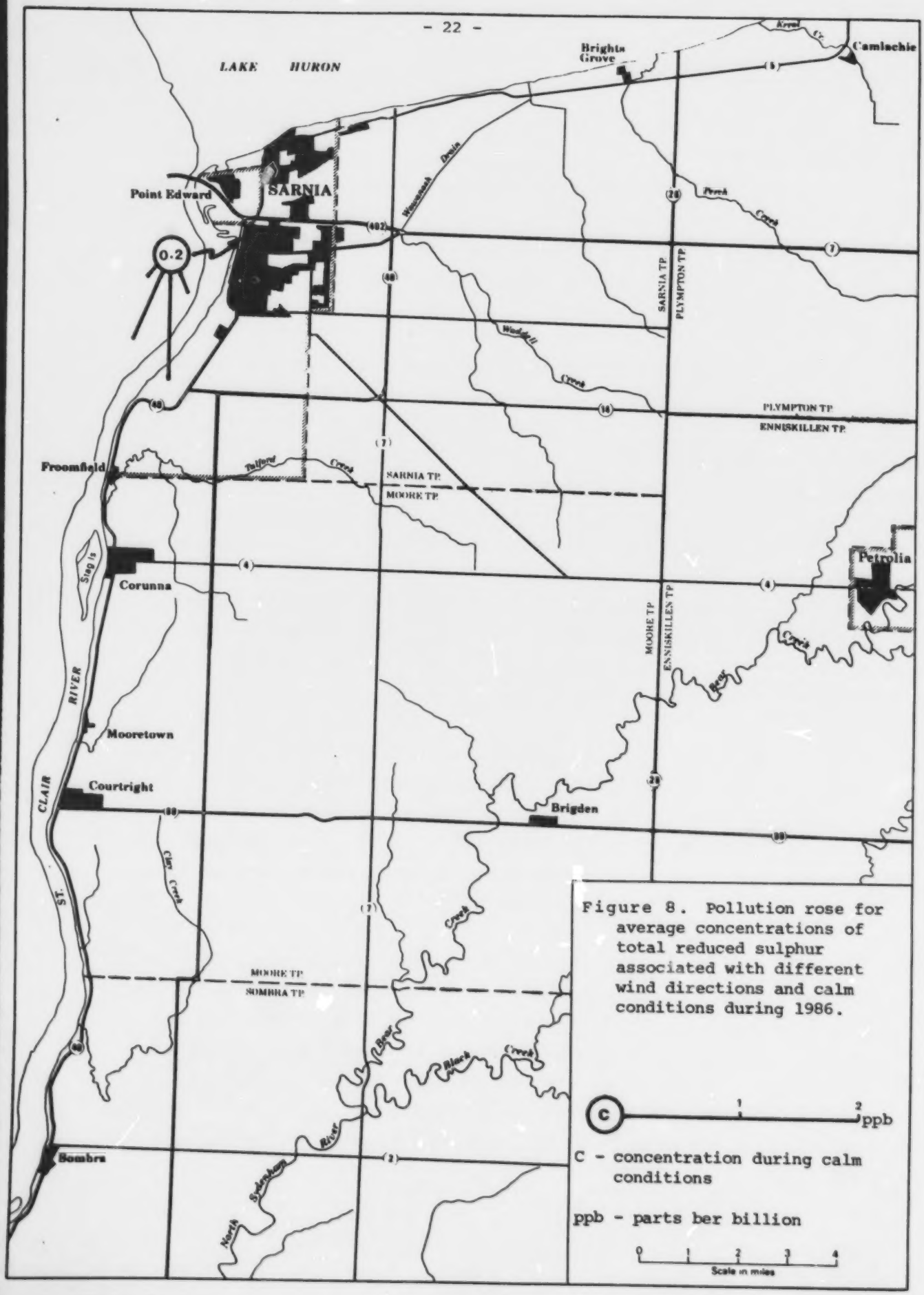



Figure 8. Pollution rose for average concentrations of total reduced sulphur associated with different wind directions and calm conditions during 1986.

C - concentration during calm conditions

ppb - parts ber billion

0 1 2 3 4
Scale in miles

## CARBON MONOXIDE

Combustion processes represent man's major emissions of carbon monoxide. Emissions from motor vehicles are most significant because they occur near ground level and are concentrated in urban areas where the public may be exposed for lengthy periods. Industries and power generating plants normally provide adequate dispersion for their emissions to prevent unsatisfactory levels of carbon monoxide in the ambient air.

The criteria for carbon monoxide, which are based on the protection of human health, are 30 ppm averaged for 1 hour and 13 ppm averaged for any consecutive 8-hour period.

During 1986 carbon monoxide was monitored at station 14064, located in the downtown core at Centennial Park. The criteria for desirable ambient air quality were not exceeded. A summary of data for carbon monoxide measured at station 14064 since 1978 is presented in Table A5, Appendix 4, and illustrates long-term conformity below established criteria.

## OXIDES OF NITROGEN

Gaseous oxides of nitrogen are emitted into the atmosphere by man through combustion processes. Nitric oxide and nitrogen dioxide are the gaseous compounds of primary interest.

Criteria for desirable ambient air quality exist for nitrogen dioxide, but not for nitric oxide or total oxides of nitrogen. The criteria, which are based on offensive odours and the protection of human health, are 0.20 ppm averaged for 1 hour and 0.10 ppm averaged for 24 hours. The 24-hour criterion has not been exceeded at station 14064 where monitoring began in 1978. The 1-hour criterion was not exceeded in 1986 and has only been exceeded once since 1978.

A summary of data for oxides of nitrogen appears in Table A5, Appendix 4. Levels are in ranges typical of communities the size of Sarnia.

Oxides of nitrogen in combination with reactive hydrocarbons and certain meteorological conditions play an important role in the formation of unsatisfactory levels of photochemical oxidants. Also, oxides of nitrogen react to form acids which are part of acidic precipitation. Therefore, consideration is being given to further controls on emissions of oxides of nitrogen. One such control to be implemented is stricter controls for emissions from 1988 model cars.

## HYDROCARBONS

Emissions from motor vehicles are a primary man-made source of hydrocarbons in ambient air. Other significant man-made sources are incomplete combustion of fuels by industries and power plants, and evaporation losses during the manufacture, use, storage and transportation of materials containing volatile hydrocarbons. Natural phenomena also produce many hydrocarbons of which methane is the most abundant.

Owing to the wide range of effects associated with different hydrocarbons at various concentrations, no criteria for desirable ambient air quality have been established for total hydrocarbons. Instead control is achieved by setting criteria for desirable levels of specific hydrocarbons in ambient air and/or establishing standards which require control of emissions of specific hydrocarbons.

Total hydrocarbons have been measured at station 14064 in Centennial Park since July, 1978. Average levels of total hydrocarbons have been similar each year. A summary of data for hydrocarbons appears in Table A5, Appendix 4.

The Ministry has conducted a number of short term intensified monitoring surveys in the Sarnia area using mobile vans. These surveys have measured numerous specific hydrocarbons at low levels.

## OXIDANTS

Oxidants in the ambient air are primarily a result of a series of photochemical reactions and inter-reactions involving oxides of nitrogen and non-methane hydrocarbons. The reactions are promoted by certain meteorological conditions such as warm temperatures and intensive sunshine, resulting in higher levels of oxidants in the spring and summer months.

Throughout 1986 the Ministry monitored oxidants in the form of ozone at station 14064 in the downtown core of Sarnia and at station 14118, situated in a rural setting approximately 10 kilometres east of Sarnia. Ozone normally accounts for 80 to 95 percent of the oxidants present in ambient air. Consequently, with technology for monitoring ozone being more accurate and efficient than for total oxidants, most regulatory agencies monitor for ozone.

Long-range transport of ozone and its precursor chemicals (oxides of nitrogen and hydrocarbons) may account for a very significant portion of local levels of ozone. Long-range transport from distances greater than 200 kilometres has been reported in the literature. Therefore, successful control of oxidants will depend on control strategies implemented in the United States as well as in Ontario. The United States and Canada have been jointly addressing the significance of long-range transport of ozone and its precursor chemicals. The U.S. Environmental Protection Agency is requiring individual states to implement control strategies that will ensure attainment of the U.S. primary air quality standard for ozone(0.12 ppm, averaged for 1 hour) by December 31, 1987. Ontario has launched a detailed study into oxidants and oxidant control strategies. Also, the proposed reductions for vehicle emissions in Canada should have a positive effect on ozone levels by reducing hydrocarbon and oxides of nitrogen levels.

In addition to ozone formed by photochemical reactions in the troposphere, ground level concentrations of ozone are occasionally increased by ozone from the stratosphere being transported downward. Ozone is naturally produced in minor amounts by lightning.

Ontario's criterion for desirable ambient air quality established for ozone is 80 parts per billion (ppb) averaged for 1 hour. This criterion was established for the protection of vegetation, property and human health. Some oxidant-related effects that are detrimental to health are eye irritation and a decrease in performance during athletic endeavors.

During 1986 the criterion was exceeded 30 times at station 14064 and 41 times at station 14118. A summary of data for ozone appears in Table A6 of Appendix 4.

Pollution roses for 1986 are presented in Figure 9 to show the frequency of the total number of excursions above the criterion associated with different wind directions. At both stations the greatest frequency of excursions are associated with southerly and south-southwesterly winds. These winds are apt to be associated with the backs of high pressure systems or the area south of low pressure fronts which have weather favourable for photochemical reactions (clear sunny skies and warm temperatures) and which promote long-range transport of oxidants and their precursor chemicals.

## FLUORIDES

In the Sarnia area fluorides are emitted into the atmosphere from fossil-fueled power plants where it exists as an impurity in coal, from a fertilizer plant where it occurs as a constituent of phosphorus rock, and from petroleum refineries where it is used as a catalyst in alkylation.

Fluoridation rate is a measurement designed to indicate relative amounts of gaseous fluoride present over an extended period of time. A lime-impregnated filter is exposed to ambient air for thirty days and subsequently analyzed for fluoride content. This technique is inexpensive compared to other methods for measuring fluorides. Some fluorides in particulate form are collected on the filters.

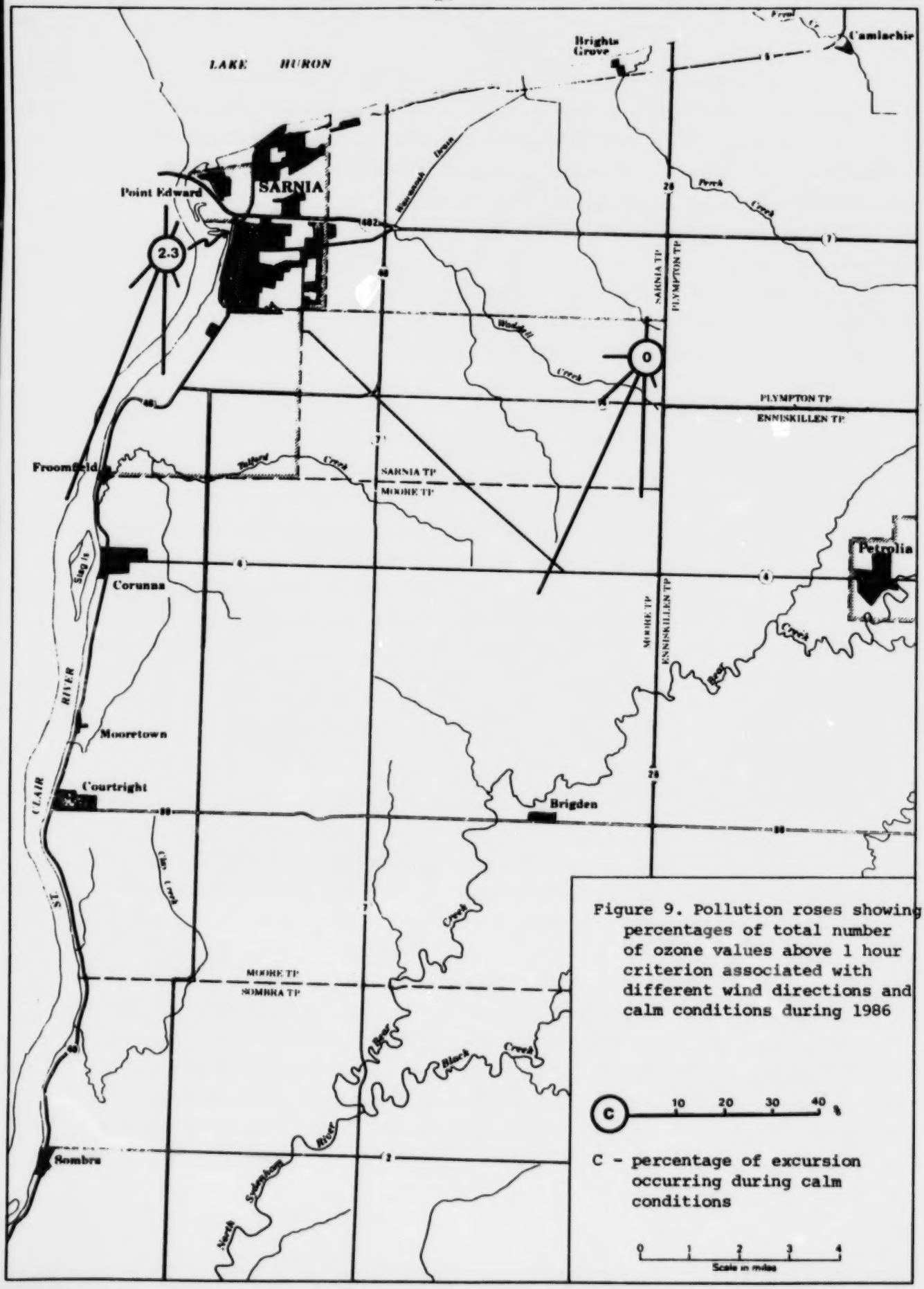



Figure 9. Pollution roses showing percentages of total number of ozone values above 1 hour criterion associated with different wind directions and calm conditions during 1986

Criteria for desirable ambient air quality established for fluoridation rate are based on protection of sensitive vegetation. A criterion of 40 micrograms of fluoride per 100 square centimetres of filter per 30 days (ug F/100 $cm^2$/30 days) exists for the growing season of April 15 to October 15. A less stringent criterion of 80 ug F/100 $cm^2$/30 days exists for the period of October 16 to April 14. Since the months of April and October are common to both criteria and fluoridation rate is determined on a monthly basis, excursions above the criteria during these months are determined by comparing fluoridation rate to the average of the two criteria (60 ug F/100 $cm^2$/30 days).

The Ministry monitors fluoridation rate at station 14004, located south of Courtright in the vicinity of the fertilizer complex of Canadian Industries Limited and power generating plants of Ontario Hydro and Detroit Edison. Canadian Industries Limited has maintained a detailed monitoring network for fluoridation rate for many years.

At Station 14004 all four fluoridation rate values determined for the growing season of 1986 were above the criterion for desirable ambient air quality. However, as in previous years, the 1986 phytotoxicology survey conducted by the Ministry did not reveal vegetation damage attributable to fluorides off company property. The lack of damage may be attributable to the absence of sensitive vegetation and other conducive environmental factors. Table 3 presents the data for fluoridation rate from 1976 through 1986.

Table 3. Fluoridation rates measured at station 14004 from 1976 to 1986 (ug F/100 $cm^2$/30 days)

| Year | Jan | Feb | March | April | May | June | July | Aug | Sept | Oct | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | | | | | | 46 | 38 | 74 | 48 | 39 | 21 | 40 | 44 |
| 1977 | 42 | 23 | 53 | 32 | 78 | 31 | | 79 | 112 | 29 | 104 | 50 | 58 |
| 1978 | 83 | 51 | 53 | 57 | 100 | 65 | 94 | 74 | 74 | 57 | 53 | 59 | 68 |
| 1979 | 32 | 63 | 25 | 56 | 54 | 64 | 68 | 129 | 89 | 49 | 32 | 26 | 57 |
| 1980 | 16 | 23 | 51 | 62 | 61 | 49 | 83 | 84 | | 36 | 28 | 31 | 48 |
| 1981 | 48 | 48 | 30 | 49 | 69 | 78 | 116 | 122 | 95 | 71 | 55 | 24 | 67 |
| 1982 | 48 | 67 | 35 | 35 | 99 | 20 | 50 | | 38 | 86 | 35 | 20 | 48 |
| 1983 | 17 | 30 | 37 | 42 | 43 | 75 | 60 | 68 | 42 | 73 | 30 | 30 | 46 |
| 1984 | 27 | 36 | 45 | 80 | 56 | 61 | 54 | 71 | 43 | 56 | 25 | 30 | 49 |
| 1985 | 37 | 27 | 34 | 40 | 39 | 47 | 45 | 89 | 58 | 31 | 50 | 32 | 44 |
| 1986 | 27 | 43 | 30 | 46 | 66 | 82 | | 57 | 96 | 41 | 29 | 53 | 52 |

NOTE: Underlined values exceeded criteria for desirable ambient air.

# APPENDIX I

# MONITORING NETWORK

Table A1. Locations of monitoring stations and parameters being monitored.

| Station No. | Location | Parameters measured | Height of measurements | Purpose of stations and comments |
|---|---|---|---|---|
| 14001 | Sarnia General Hospital | Suspended particulates | 16 m. | Historical station which has been in operation since 1962. Does not reflect ground level concentrations but does indicate more direct effects of particulates from high stacks and long-range transport. |
| 14004 | 5 1/2 miles south of Courtright | Fluoridation rate | 4 m. | Monitors fluorides from fertilizer industry. |
| 14016 | 1 1/4 miles south of Courtright | Suspended particulates<br>continuous $SO_2$,<br>WS, WD, Temp.,<br>WS, WD, Temp.,<br>WS, WD, Temp., telemetering equipment | 1 m.<br>10 m.<br>30 m.<br>92 m. | Monitors suspended particulates and sulphur dioxide in relation to power generating plants. Provides meteorological data required for stability forecasts and air quality interpretations. |
| 14030 | R. R. #1 Corunna | Suspended particulates | 3 m. | Monitors particulates in the vicinity of of Tricil Limited. |
| 14031 | R. R. #1 Mooretown | Suspended particulates | 3 m. | Monitors particulates in the vicinity of Tricil Limited. |
| 14049 | Victoria Street | Continuous $SO_2$, CO, NO, $NO_2$, $NO_x$, $O_3$, total hydrocarbons, and suspended particulates | 4 m. | Monitored air pollutants in a heavily populated area where the pollutants from traffic, commercial establishments and the heavily industrialized complex south of the monitoring station should be high relative to residential areas. This site was terminated in 1978 and the instruments moved to station 14064. |

Table A1. continued

| Station No. | Location | Parameters measured | Height of measurements | Purpose of stations and comments |
|---|---|---|---|---|
| 14054 | Sarnia Yacht Club | Suspended particulates | 5 m. | Monitors suspended particulates in the north Sarnia-Point Edward area. |
| 14059 | Riverbend, Corunna | Suspended particulates | 4 m. | Monitors suspended particulates in the residential area of Corunna which is surrounded by industry and generating stations. |
| 14064 | Centennial Park Front Street, Sarnia | Continuous $SO_2$, CO, NO, $NO_2$, $NO_x$, $O_3$, total hydrocarbons, total reduced sulphur. 1-hr COH, suspended particulates, telemetering equipment | 3 m. | Monitors main air pollutants in an area adjacent to downtown Sarnia and in line with many point sources of pollution located to the south of the downtown area. Provides Air Pollution Index for Sarnia. |
| 14118 | Mandamin, 5 miles west of Wyoming | $O_3$ | 5 m. | Monitors ozone levels in a rural location |
| 14151 | Front and David Streets, downtown Sarnia | Suspended particulates | 3 m. | Monitors pollutants in commercial area which is also affected by heavily industrialized area to south. Since this is the location of a monitoring station operated by the Lambton Industrial Society, cross checking of monitoring techniques is possible. |

Table A2. Desirable ambient air quality criteria established by the Ontario Ministry of the Environment

| Parameter | Desirable ambient air quality criteria | Prime reasons for establishing criteria or monitoring parameter |
|---|---|---|
| Carbon monoxide | 30 ppm averaged for 1 hour<br>13 ppm averaged for 8 hours | Protection of human health<br>Protection of human health |
| Fluoridation rate | 40 ug of fluorides/100 $cm^2$ of limed filter paper in 30 days during April 15 to October 15 | Protection of vegetation |
| | 80 ug of fluorides/100 $cm^2$ of limed filter paper in 30 days during October 16 to April 14 | Protection of vegetation (less restrictive criterion during the non-growing season) |
| Hydrocarbons (total) | None | Effects of hydrocarbons vary widely depending on their chemical-physical nature |
| Hydrogen Sulphide | 0.02 ppm averaged for 1 hour | Protection against offensive odours |
| Mercaptans | 0.01 ppm averaged for 1 hour | Protection against offensive odours |
| Nitric oxide | None | Reacts with oxygen to produce $NO_2$ |
| Nitrogen dioxide | 0.20 ppm averaged for 1 hour | Protection of human health and protection against odours |
| | 0.10 ppm averaged for 24 hours | Protection of human health and protection against odours |
| Oxides of nitrogen | None | |

Table A2. continued

| Parameter | Desirable ambient air quality criteria | Prime reasons for establishing criteria or monitoring parameter |
|---|---|---|
| Ozone | 0.08 ppm averaged for 1 hour | Protection of vegetation, adverse health effects |
| Sulphur dioxide | 0.25 ppm averaged for 1 hour | Protection of vegetation |
| | 0.10 ppm averaged for 1 day (24 hours) | Protection of human health |
| | 0.02 ppm averaged for 1 year | Protection of vegetation |
| Suspended particulates | 120 ug/$m^3$ averaged for 24 hours | Based on health effects in conjunction with elevated levels of $SO_2$ and impairment of visibility. |
| | A geometric mean of 60 ug/$m^3$ during 1 year | Based on public awareness of visible pollution |
| Cadmium in suspended particulates | 2.0 ug/$m^3$ averaged for 24 hours | Protection of human health |
| Lead in suspended particulates | 5 ug/$m^3$ averaged for 24 hours | Protection of human health |
| | A geometric mean of 2 ug/$m^3$ over a 30-day period | Protection of human health |
| Nickel in suspended particulates | 2.0 ug/$m^3$ averaged for 24 hours | Protection of vegetation |
| Vanadium in suspended particulates | 2.0 ug/$m^3$ averaged for 24 hours | Protection of human health |

# APPENDIX 2

## METEOROLOGICAL DATA

Table A3. Percent frequencies of wind directions at the 30-metre level of station 14016.

| Year | N | NE | E | SE | S | SW | W | NW |
|---|---|---|---|---|---|---|---|---|
| 1986 | 12.6 | 8.4 | 7.6 | 8.4 | 18.0 | 18.9 | 12.2 | 14.1 |
| 1985 | 12.2 | 10.0 | 5.7 | 7.2 | 20.5 | 19.0 | 12.7 | 12.8 |
| 1984 | 12.6 | 9.8 | 6.1 | 8.2 | 22.1 | 15.6 | 11.0 | 14.7 |
| 1983 | 13.5 | 10.6 | 7.5 | 9.3 | 18.9 | 15.6 | 10.2 | 14.4 |
| 1982 | 12.1 | 9.5 | 5.2 | 8.9 | 22.4 | 16.4 | 12.6 | 12.9 |
| 1981 | 13.8 | 9.9 | 4.5 | 7.8 | 18.6 | 15.8 | 11.9 | 17.7 |
| 1980 | 12.6 | 8.6 | 5.6 | 7.5 | 20.1 | 15.1 | 14.4 | 16.1 |
| 1979 | 10.7 | 8.7 | 6.5 | 8.9 | 24.7 | 14.7 | 11.9 | 14.0 |
| 1978 | 13.6 | 12.7 | 6.3 | 6.0 | 19.0 | 17.2 | 11.9 | 13.3 |
| 1977 | 11.3 | 9.8 | 5.3 | 7.2 | 18.5 | 21.2 | 14.1 | 12.6 |
| 1976 | 12.2 | 9.2 | 3.5 | 4.7 | 18.1 | 20.5 | 15.1 | 16.7 |

# APPENDIX 3

# PARTICULATES

Table A4. Concentrations ($ug/m^3$) of various constituents of suspended particulates: 1976 to 1986.

| Station and Year | Cadmium # of samples | Cadmium Avg. | Cadmium Max. | Chromium # of samples | Chromium Avg. | Chromium Max. | Copper # of samples | Copper Avg. | Copper Max. | Iron # of samples | Iron Avg. | Iron Max. | Lead # of samples | Lead Avg. | Lead Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14016 | | | | | | | | | | | | | | | |
| 1976 | 18 | 0.000 | 0.003 | 18 | 0.003 | 0.011 | 18 | 0.41 | 1.17 | 18 | 0.6 | 1.6 | 18 | 0.2 | 0.4 |
| 1977 | 21 | 0.000 | 0.002 | 21 | 0.008 | 0.025 | 21 | 0.31 | 0.58 | 21 | 0.6 | 1.8 | 21 | 0.2 | 0.6 |
| 1978 | 26 | 0.001 | 0.003 | 26 | 0.007 | 0.019 | 26 | 0.50 | 1.38 | 26 | 0.9 | 3.2 | 26 | 0.1 | 0.4 |
| 1979 | 35 | 0.001 | 0.004 | 35 | 0.002 | 0.010 | 35 | 0.39 | 1.01 | 35 | 0.8 | 2.9 | 35 | 0.2 | 0.6 |
| 1980 | 25 | 0.001 | 0.004 | 25 | 0.002 | 0.009 | 25 | 0.44 | 0.96 | 25 | 0.6 | 1.8 | 25 | 0.1 | 0.4 |
| 1981 | 124 | 0.001 | 0.004 | 124 | 0.003 | 0.014 | 124 | 0.19 | 1.59 | 124 | 0.6 | 2.6 | 124 | 0.1 | 0.3 |
| 1982 | 338 | 0.001 | 0.004 | 328 | 0.002 | 0.116 | 339 | 0.28 | 1.71 | 308 | 0.4 | 3.1 | 328 | 0.1 | 0.4 |
| 1983 | 339 | 0.001 | 0.004 | 332 | 0.002 | 0.015 | 339 | 0.34 | 1.72 | 339 | 0.5 | 3.6 | 340 | 0.1 | 0.4 |
| 1984 | 332 | 0.001 | 0.006 | 332 | 0.003 | 0.038 | 332 | 0.43 | 2.91 | 332 | 0.5 | 2.7 | 332 | 0.1 | 0.3 |
| 1985 | 336 | 0.001 | 0.006 | 336 | 0.006 | 0.036 | 336 | 0.39 | 2.36 | 336 | 0.5 | 3.0 | 336 | 0.1 | 0.2 |
| 1986 | 340 | 0.001 | 0.006 | 340 | 0.004 | 0.067 | 340 | 0.21 | 0.82 | 340 | 0.4 | 2.0 | 340 | 0.0 | 0.2 |
| 14030 | | | | | | | | | | | | | | | |
| 1978 | 11 | 0.002 | 0.004 | 11 | 0.007 | 0.019 | 11 | 0.37 | 0.98 | 11 | 1.2 | 2.2 | 11 | 0.3 | 0.9 |
| 1979 | 50 | 0.001 | 0.004 | 50 | 0.007 | 0.022 | 50 | 0.32 | 1.36 | 55 | 0.6 | 2.2 | 54 | 0.1 | 0.4 |
| 1980 | 52 | 0.001 | 0.004 | 52 | 0.003 | 0.023 | 52 | 0.47 | 2.34 | 52 | 0.5 | 1.5 | 52 | 0.1 | 0.3 |
| 1981 | 58 | 0.001 | 0.009 | 58 | 0.005 | 0.053 | 58 | 0.17 | 0.56 | 58 | 0.7 | 4.5 | 58 | 0.1 | 1.4 |
| 1982 | 58 | 0.001 | 0.002 | 55 | 0.003 | 0.010 | 58 | 0.11 | 0.29 | 48 | 0.5 | 3.5 | 56 | 0.1 | 0.7 |
| 1983 | 54 | 0.001 | 0.004 | 55 | 0.003 | 0.018 | 57 | 0.17 | 0.45 | 57 | 0.4 | 1.4 | 57 | 0.1 | 0.2 |
| 1984 | 55 | 0.001 | 0.002 | 55 | 0.005 | 0.026 | 55 | 0.18 | 0.49 | 55 | 0.4 | 2.0 | 55 | 0.1 | 0.4 |
| 1985 | 58 | 0.001 | 0.004 | 58 | 0.007 | 0.055 | 58 | 0.11 | 0.25 | 58 | 0.5 | 3.0 | 58 | 0.1 | 0.1 |
| 1986 | 53 | 0.000 | 0.003 | 53 | 0.004 | 0.021 | 53 | 0.10 | 0.26 | 53 | 0.4 | 1.4 | 53 | 0.0 | 0.1 |

Table A4. continued

| Station and Year | Cadmium # of samples | Cadmium Avg. | Cadmium Max. | Chromium # of samples | Chromium AVg. | Chromium Max. | Copper # of samples | Copper Avg. | Copper Max. | Iron # of samples | Iron Avg. | Iron Max. | Lead # of samples | Lead Avg. | Lead Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14031 | | | | | | | | | | | | | | | |
| 1978 | 12 | 0.002 | 0.003 | 12 | 0.004 | 0.008 | 12 | 0.44 | 1.00 | 12 | 0.7 | 1.3 | 12 | 0.1 | 0.3 |
| 1979 | 54 | 0.001 | 0.005 | 54 | 0.010 | 0.189 | 54 | 0.25 | 0.97 | 58 | 0.5 | 2.7 | 54 | 0.1 | 0.4 |
| 1980 | 54 | 0.001 | 0.004 | 54 | 0.005 | 0.030 | 54 | 0.13 | 0.26 | 54 | 0.5 | 2.2 | 54 | 0.1 | 0.3 |
| 1981 | 58 | 0.001 | 0.003 | 58 | 0.005 | 0.035 | 58 | 0.15 | 0.95 | 58 | 0.6 | 2.6 | 58 | 0.1 | 0.2 |
| 1982 | 54 | 0.000 | 0.002 | 56 | 0.004 | 0.010 | 58 | 0.13 | 0.29 | 50 | 0.5 | 3.7 | 56 | 0.1 | 0.6 |
| 1983 | 55 | 0.001 | 0.001 | 53 | 0.002 | 0.012 | 55 | 0.25 | 1.54 | 55 | 0.6 | 2.3 | 55 | 0.1 | 0.3 |
| 1984 | 50 | 0.001 | 0.002 | 50 | 0.004 | 0.032 | 50 | 0.14 | 0.37 | 50 | 0.5 | 1.9 | 50 | 0.1 | 0.1 |
| 1985 | 55 | 0.001 | 0.004 | 55 | 0.007 | 0.029 | 55 | 0.06 | 0.13 | 55 | 0.6 | 2.3 | 55 | 0.1 | 0.1 |
| 1986 | 50 | 0.000 | 0.003 | 50 | 0.006 | 0.024 | 50 | 0.07 | 0.16 | 50 | 0.3 | 1.1 | 50 | 0.0 | 0.1 |
| 14064 | | | | | | | | | | | | | | | |
| 1981 | 57 | 0.001 | 0.004 | 57 | 0.003 | 0.013 | 57 | 0.17 | 0.86 | 57 | 0.7 | 2.3 | 59 | 0.1 | 0.6 |
| 1982 | 52 | 0.001 | 0.008 | 47 | 0.002 | 0.009 | 52 | 0.21 | 1.66 | 53 | 0.7 | 2.9 | 50 | 0.2 | 1.1 |
| 1983 | 57 | 0.001 | 0.003 | 57 | 0.002 | 0.009 | 57 | 0.62 | 2.50 | 57 | 0.7 | 1.8 | 56 | 0.2 | 0.6 |
| 1984 | 57 | 0.001 | 0.002 | 57 | 0.002 | 0.015 | 57 | 0.43 | 2.00 | 57 | 0.5 | 1.7 | 57 | 0.2 | 0.3 |
| 1985 | 57 | 0.001 | 0.003 | 57 | 0.006 | 0.012 | 57 | 0.11 | 0.39 | 57 | 0.6 | 2.3 | 57 | 0.1 | 0.3 |
| 1986 | 57 | 0.000 | 0.002 | 57 | 0.005 | 0.023 | 57 | 0.20 | 0.64 | 57 | 0.5 | 1.5 | 57 | 0.1 | 0.3 |

Table A4. continued

| Station and Year | Manganese # of samples | Manganese Avg. | Manganese Max. | Nickel # of samples | Nickel Avg. | Nickel Max. | Nitrate # of samples | Nitrate Avg. | Nitrate Max. | Sulphate # of samples | Sulphate Avg. | Sulphate Max. | Vanadium # of samples | Vanadium Avg. | Vanadium Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14016 | | | | | | | | | | | | | | | |
| 1976 | 8 | 0.01 | 0.04 | 18 | 0.013 | 0.031 | 96 | 4.0 | 20.0 | 105 | 8.7 | 33.4 | 18 | 0.00 | 0.02 |
| 1977 | 21 | 0.03 | 0.09 | 21 | 0.022 | 0.165 | 54 | 3.7 | 27.8 | 54 | 10.0 | 24.6 | 21 | 0.01 | 0.09 |
| 1978 | 26 | 0.02 | 0.06 | 26 | 0.016 | 0.194 | 53 | 4.6 | 24.6 | 53 | 11.2 | 35.3 | 26 | 0.00 | 0.10 |
| 1979 | 35 | 0.02 | 0.07 | 35 | 0.008 | 0.042 | 56 | 5.4 | 14.8 | 56 | 12.4 | 41.0 | 35 | 0.00 | 0.01 |
| 1980 | 25 | 0.02 | 0.10 | 25 | 0.010 | 0.064 | 56 | 4.8 | 11.4 | 56 | 11.5 | 25.1 | 25 | 0.01 | 0.10 |
| 1981 | 124 | 0.02 | 0.12 | 124 | 0.005 | 0.045 | 128 | 4.2 | 13.5 | 126 | 8.7 | 37.0 | 124 | 0.01 | 0.08 |
| 1982 | 339 | 0.01 | 0.10 | 339 | 0.006 | 0.100 | 339 | 3.5 | 23.3 | 339 | 9.3 | 48.7 | 338 | 0.01 | 0.14 |
| 1983 | 339 | 0.01 | 0.12 | 328 | 0.005 | 0.031 | 340 | 3.1 | 9.5 | 340 | 8.4 | 46.0 | 339 | 0.01 | 0.21 |
| 1984 | 322 | 0.02 | 0.51 | 327 | 0.006 | 0.054 | 332 | 3.2 | 16.2 | 320 | 7.8 | 33.5 | 332 | 0.01 | 0.08 |
| 1985 | 336 | 0.02 | 0.12 | 336 | 0.006 | 0.037 | 336 | 2.9 | 20.7 | 336 | 7.0 | 22.2 | 336 | 0.01 | 0.09 |
| 1986 | 340 | 0.01 | 0.12 | 340 | 0.003 | 0.041 | 339 | 3.6 | 18.6 | 339 | 7.8 | 21.1 | 340 | 0.01 | 0.12 |
| 14030 | | | | | | | | | | | | | | | |
| 1978 | | | | 11 | 0.009 | 0.013 | | | | | | | | | |
| 1979 | 45 | 0.01 | 0.05 | 50 | 0.006 | 0.032 | | | | | | | 45 | 0.00 | 0.02 |
| 1980 | 50 | 0.01 | 0.08 | 52 | 0.004 | 0.026 | | | | | | | 50 | 0.00 | 0.01 |
| 1981 | 51 | 0.02 | 0.10 | 56 | 0.004 | 0.034 | | | | | | | 51 | 0.01 | 0.03 |
| 1982 | 57 | 0.01 | 0.07 | 58 | 0.003 | 0.009 | | | | | | | 58 | 0.01 | 0.02 |
| 1983 | 56 | 0.01 | 0.03 | 56 | 0.002 | 0.009 | | | | | | | 57 | 0.00 | 0.02 |
| 1984 | 55 | 0.01 | 0.05 | 51 | 0.004 | 0.046 | | | | | | | 55 | 0.00 | 0.06 |
| 1985 | 58 | 0.02 | 0.09 | 58 | 0.005 | 0.017 | | | | | | | 58 | 0.01 | 0.02 |
| 1986 | 53 | 0.01 | 0.05 | 53 | 0.003 | 0.032 | | | | | | | 53 | 0.01 | 0.03 |

Table A4. continued

| Station and Year | Manganese # of samples | Manganese Avg. | Manganese Max. | Nickel # of samples | Nickel Avg. | Nickel Max. | Nitrate # of samples | Nitrate Avg. | Nitrate Max. | Sulphate # of samples | Sulphate Avg. | Sulphate Max. | Vanadium # of samples | Vanadium Avg. | Vanadium Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14031 | | | | | | | | | | | | | | | |
| 1978 | | | | 12 | 0.016 | 0.057 | | | | | | | | | |
| 1979 | 46 | 0.02 | 0.07 | 54 | 0.009 | 0.171 | | | | | | | 46 | 0.00 | 0.01 |
| 1980 | 52 | 0.02 | 0.11 | 54 | 0.005 | 0.021 | | | | | | | 47 | 0.01 | 0.02 |
| 1981 | 52 | 0.02 | 0.14 | 58 | 0.004 | 0.020 | | | | | | | 52 | 0.01 | 0.02 |
| 1982 | 57 | 0.01 | 0.05 | 55 | 0.003 | 0.013 | | | | | | | 58 | 0.00 | 0.02 |
| 1983 | 55 | 0.01 | 0.04 | 55 | 0.002 | 0.016 | | | | | | | 55 | 0.00 | 0.03 |
| 1984 | 50 | 0.02 | 0.05 | 50 | 0.004 | 0.039 | | | | | | | 50 | 0.00 | 0.03 |
| 1985 | 55 | 0.02 | 0.05 | 55 | 0.005 | 0.018 | | | | | | | 55 | 0.01 | 0.03 |
| 1986 | 50 | 0.01 | 0.04 | 50 | 0.002 | 0.011 | | | | | | | 50 | 0.01 | 0.13 |
| 14064 | | | | | | | | | | | | | | | |
| 1981 | 57 | 0.02 | 0.07 | 57 | 0.008 | 0.056 | 57 | 4.7 | 16.2 | 57 | 10.9 | 29.5 | 57 | 0.02 | 0.12 |
| 1982 | 52 | 0.03 | 0.21 | 53 | 0.009 | 0.067 | 51 | 4.3 | 15.6 | 51 | 10.3 | 32.6 | 52 | 0.01 | 0.11 |
| 1983 | 57 | 0.03 | 0.13 | 45 | 0.007 | 0.053 | 57 | 4.8 | 16.2 | 57 | 11.2 | 29.7 | 57 | 0.02 | 0.17 |
| 1984 | 57 | 0.02 | 0.14 | 57 | 0.005 | 0.037 | 57 | 3.5 | 15.8 | 57 | 8.0 | 19.9 | 57 | 0.01 | 0.10 |
| 1985 | 57 | 0.03 | 0.21 | 57 | 0.007 | 0.027 | 57 | 3.3 | 10.1 | 57 | 7.5 | 25.8 | 57 | 0.01 | 0.06 |
| 1986 | 57 | 0.02 | 0.12 | 57 | 0.004 | 0.030 | 57 | 3.6 | 10.7 | 57 | 8.2 | 23.8 | 57 | 0.01 | 0.09 |

# APPENDIX 4

## TOTAL REDUCED SULPHUR
## CARBON MONOXIDE, OXIDES OF NITROGEN,
## HYDROCARBONS AND OZONE

Table A5. Summary of data for total reduced sulphurs, carbon monoxide, oxides of nitrogen and hydrocarbons.

| Pollutant and Criteria | Station number | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1986 | 1985 | 1984 | 1983 | 1982 | 1981 | 1980 | 1979 | 1978 |
| Total reduced sulphur | | | | | | | | | | |
| Annual average (ppm) | 14064 | 0.000 | 0.000 | 0.001 (b) | | | | | | |
| Percentage of values above 1-hr criterion[(a)] | 14064 | 0.00 | 0.02 | 0.19 (b) | | | | | | |
| Carbon Monoxide | | | | | | | | | | |
| Annual average (ppm) | 14064 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Percentage of values above: 1-hr criterion | 14064 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8-hr criterion | 14064 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note: (a) Criterion for hydrogen sulphide
(b) 4 months of data

Table A5. continued

| Pollutant and Criteria | Station number | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1986 | 1985 | 1984 | 1983 | 1982 | 1981 | 1980 | 1979 | 1978 |
| Nitric oxide | | | | | | | | | | |
| Annual average (ppm) | 14064 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 |
| Nitrogen dioxide | | | | | | | | | | |
| Annual average (ppm) | 14064 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Percentage of values above: 1-hr criterion | 14064 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 |
| 24-hr criterion | 14064 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total oxides of nitrogen | | | | | | | | | | |
| Annual average (ppm) | 14064 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 | 0.03 |
| Total hydrocarbons | | | | | | | | | | |
| Annual average (ppm) | 14064 | 1.6 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 1.9 | 2.0 | 1.7 |

Table A6. Summary of data for ozone

| Station and Parameter | Year 1986 | 1985 | 1984 | 1983 | 1982 | 1981 | 1980 | 1979 | 1978 | 1977 |
|---|---|---|---|---|---|---|---|---|---|---|
| Station 14064 | | | | | | | | | | |
| Annual average (ppm) | 0.021 | 0.023 | 0.023 | 0.023 | 0.023 | 0.021 | 0.022 | 0.023 | 0.018[a] | |
| Number of values above 1-hr criterion | 30 | 47 | 80 | 116 | 56 | 67 | 68 | 130 | 56[a] | |
| Percentage of values above 1-hr criterion | 0.4 | 0.6 | 1.0 | 1.4 | 0.7 | 0.8 | 0.8 | 1.6 | 1.4[a] | |
| Station 14118 | | | | | | | | | | |
| Annual average (ppm) | 0.024 | 0.028 | 0.026 | 0.019 | 0.023 | 0.023 | 0.022 | 0.027 | 0.029 | 0.027 |
| Number of values above 1-hr criterion | 41 | 25 | 120 | 16 | 10 | 85 | 39 | 138 | 249 | 182 |
| Percentage of values above 1-hr criterion | 0.5 | 0.6 [a] | 1.6 | 0.2 | 0.1 | 1.0 | 0.5 | 1.7 | 3.5 | 2.6 |

Note: [a] based on 6 months data